US009062884B2

(12) **United States Patent**
Rudrapatna et al.

(10) **Patent No.: US 9,062,884 B2**
(45) **Date of Patent: Jun. 23, 2015**

(54) **COMBUSTORS WITH QUENCH INSERTS**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1029 days.

(21) Appl. No.: **13/116,897**

(22) Filed: **May 26, 2011**

(65) **Prior Publication Data**

US 2012/0297778 A1 Nov. 29, 2012

(51) **Int. Cl.**
F23R 3/04 (2006.01)
F23R 3/06 (2006.01)

(52) **U.S. Cl.**
CPC ***F23R 3/045*** (2013.01); *Y10T 29/49348* (2015.01); ***F23R 3/06*** (2013.01); *Y02T 50/675* (2013.01)

(58) **Field of Classification Search**
CPC F23R 3/045; F23R 3/06; F23R 3/002; F23R 3/04; Y02T 50/675
USPC 60/752–760, 796, 798
See application file for complete search history.

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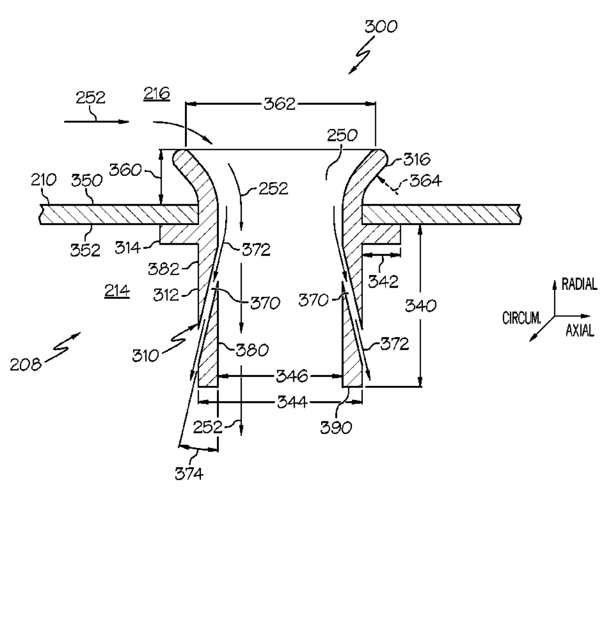
(57) **ABSTRACT**

A combustor is provided for a turbine engine. The combustor includes a first liner having a first hot side and a first cold side; a second liner having a second hot side and a second cold side, the second hot side and the first hot side forming a combustion chamber therebetween. The combustion chamber is configured to receive an air-fuel mixture for combustion therein. The combustor further includes an insert having a body portion extending through the first liner and terminating at a tip, the body portion configured to direct air flow into the combustion chamber. The insert further includes a cooling hole defined in the body portion and configured to direct a first portion of the air flow toward the tip as cooling air.

7 Claims, 10 Drawing Sheets



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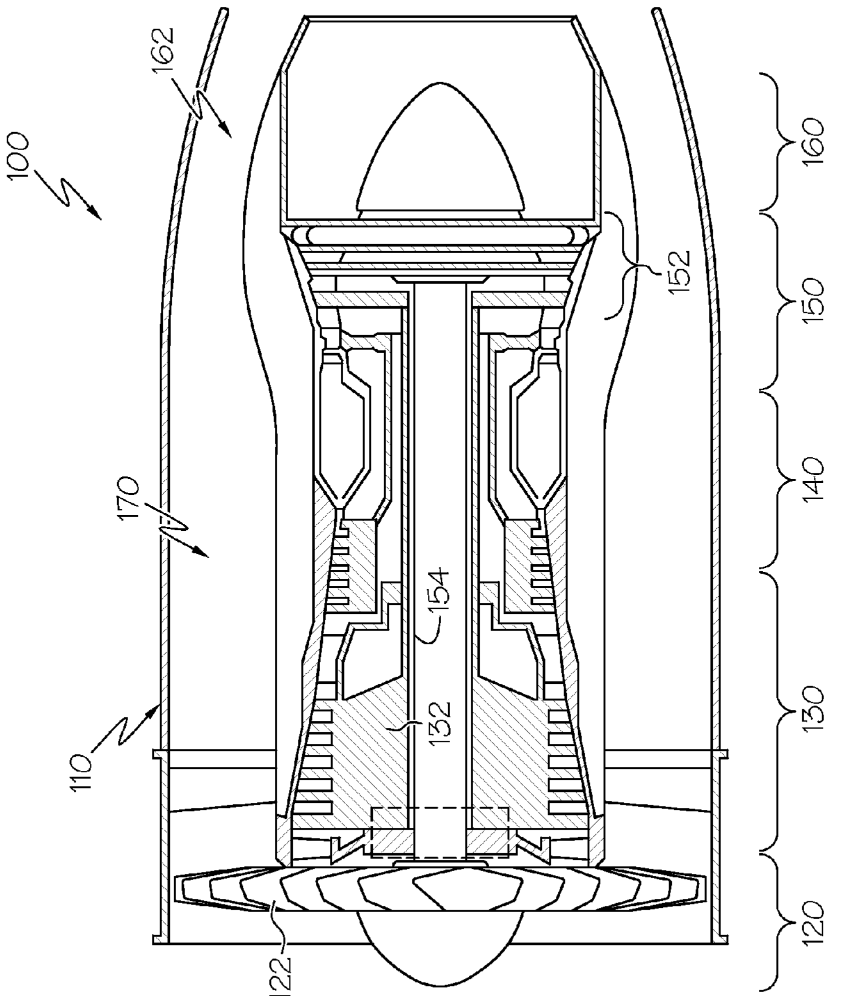


FIG. 1

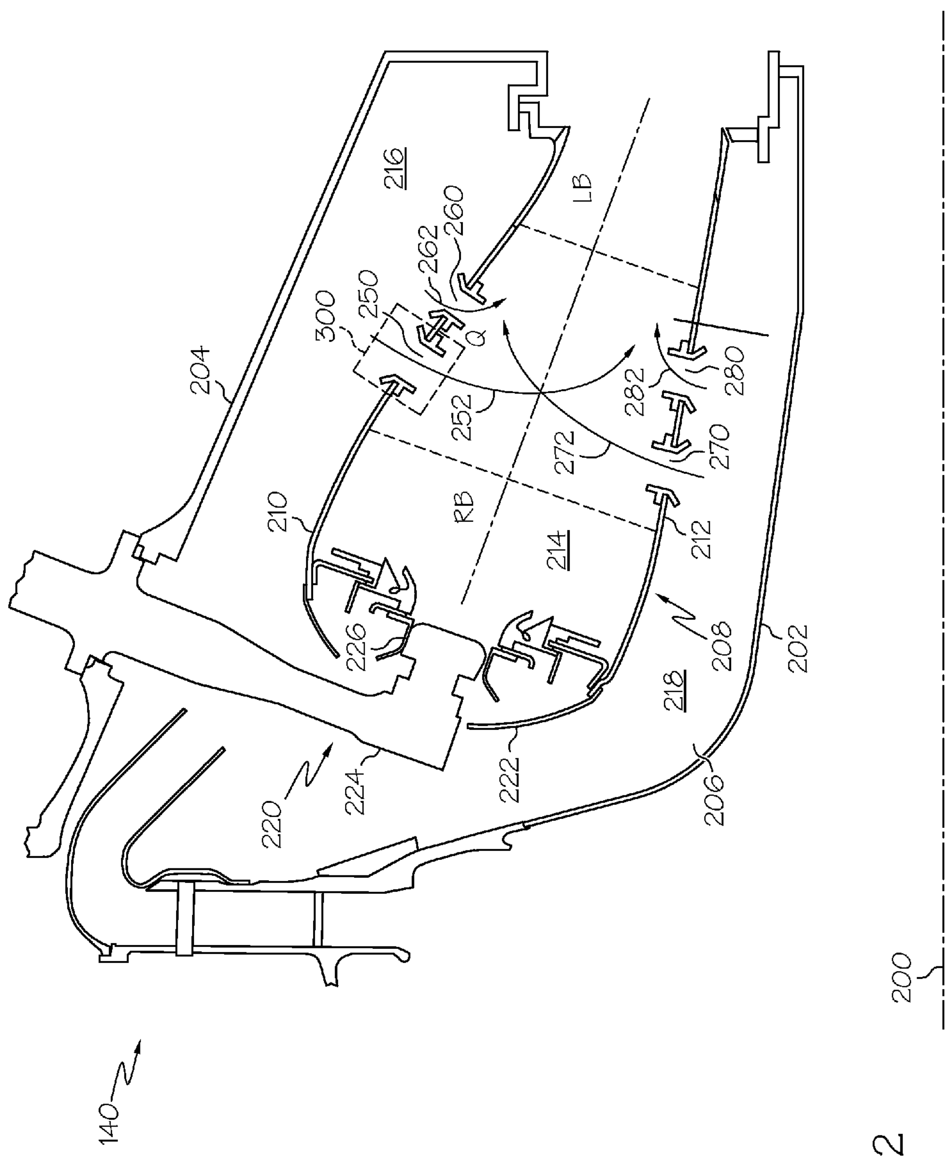
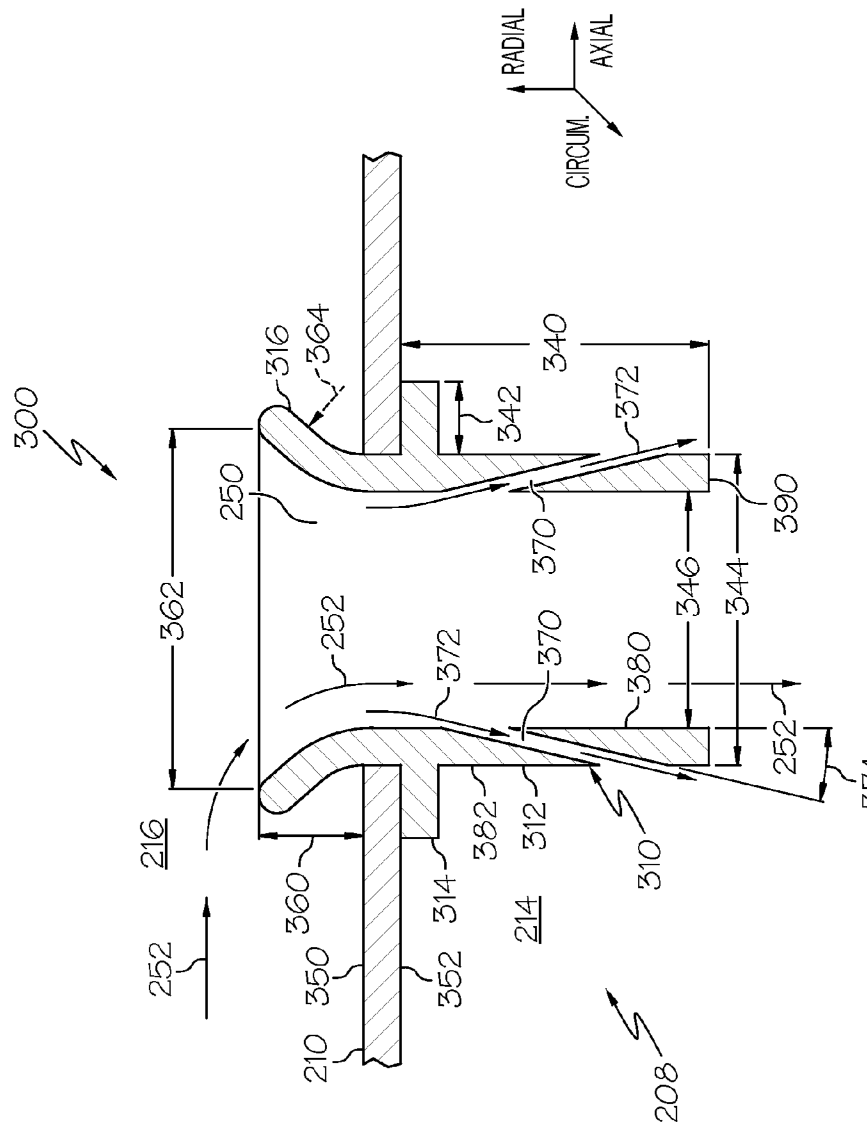

140
200
202
204
206
208
210
212
214
216
218
220
222
224
226
250
252
260
262
270
272
280
282
300
Q
RB
LB

FIG. 2



RADIAL
AXIAL
CIRCUM.
300
316
364
340
342
372
250
370
390
362
252
372
370
380
346
344
216
360
314
382
312
310
252
374
252
350
352
214
210
208

FIG. 3

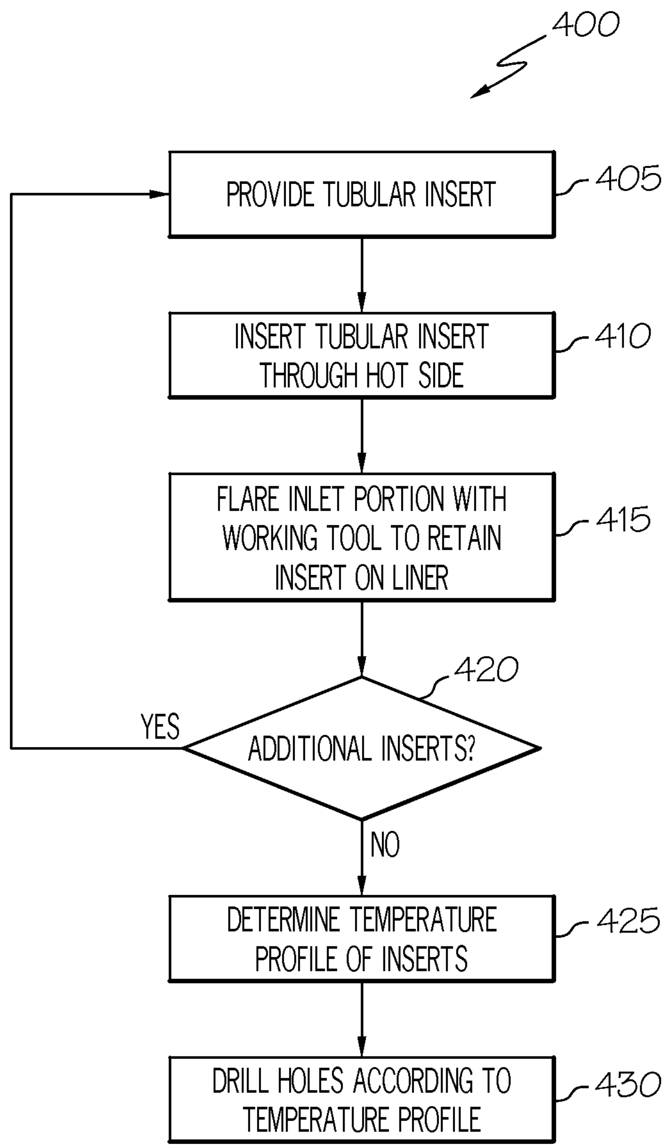

400
PROVIDE TUBULAR INSERT
405
INSERT TUBULAR INSERT THROUGH HOT SIDE
410
FLARE INLET PORTION WITH WORKING TOOL TO RETAIN INSERT ON LINER
415
420
YES
ADDITIONAL INSERTS?
NO
DETERMINE TEMPERATURE PROFILE OF INSERTS
425
DRILL HOLES ACCORDING TO TEMPERATURE PROFILE
430

FIG. 4

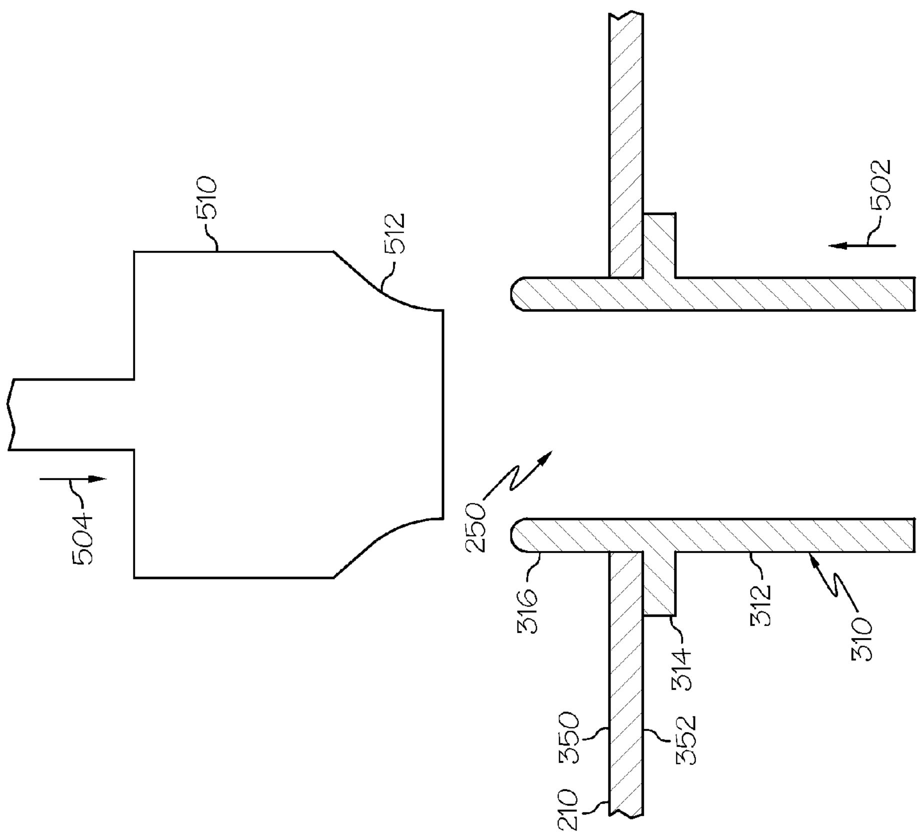


FIG. 5

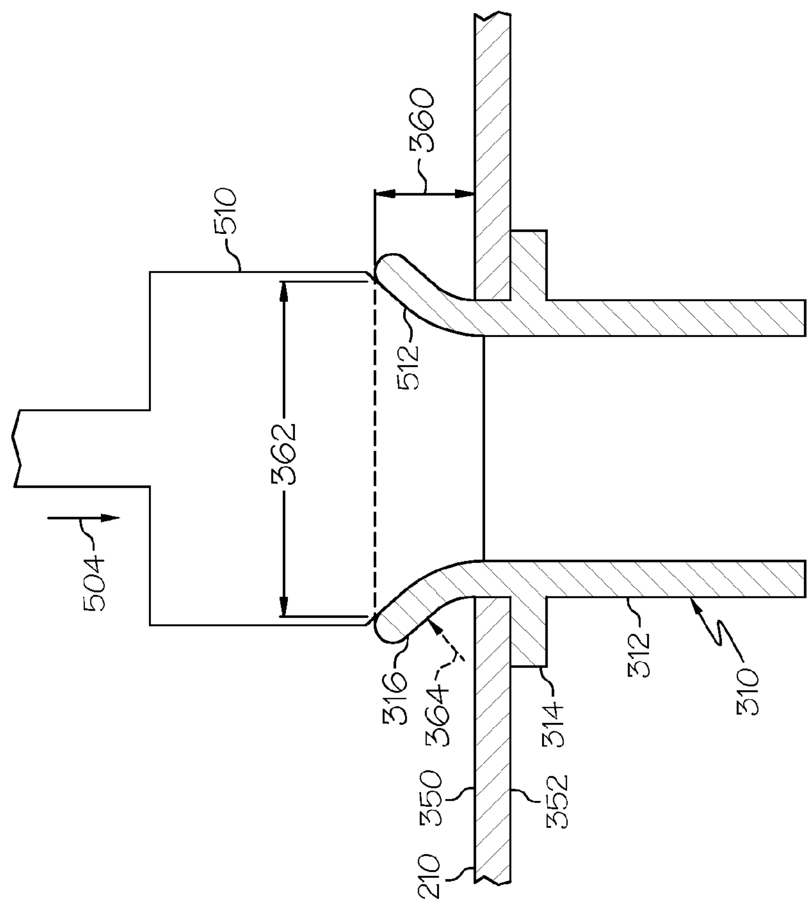


FIG. 6

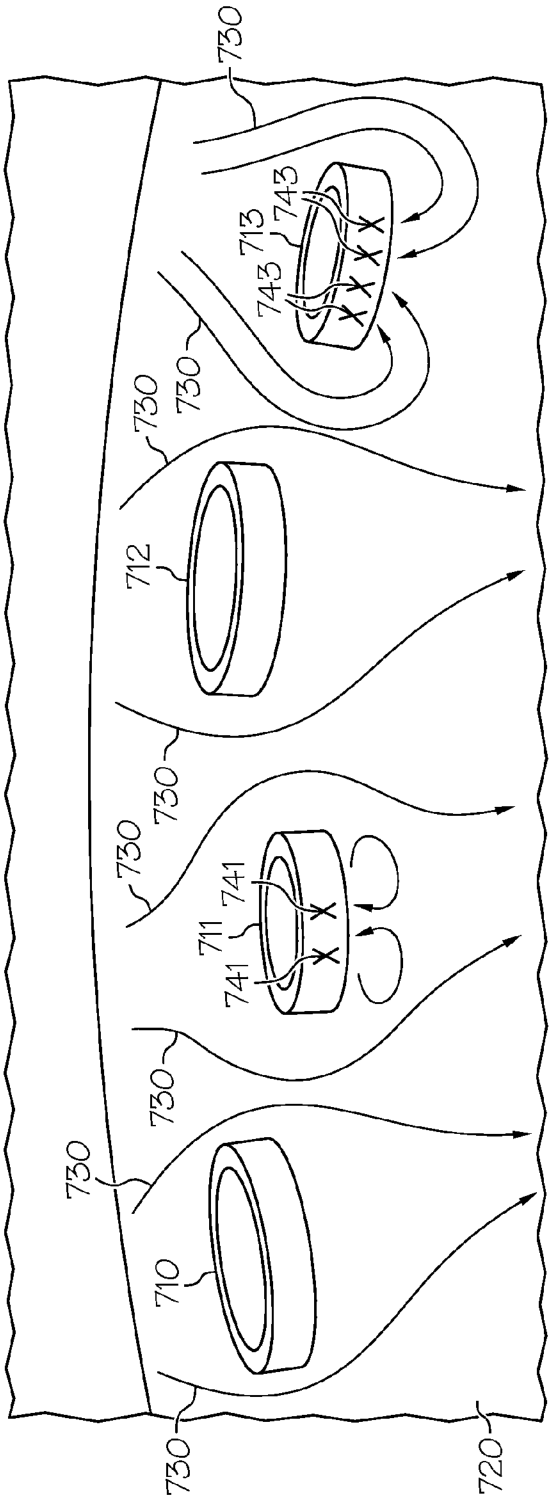

730
743
713
743
730
730
712
730
730
741
711
741
730
730
710
730
720

FIG. 7

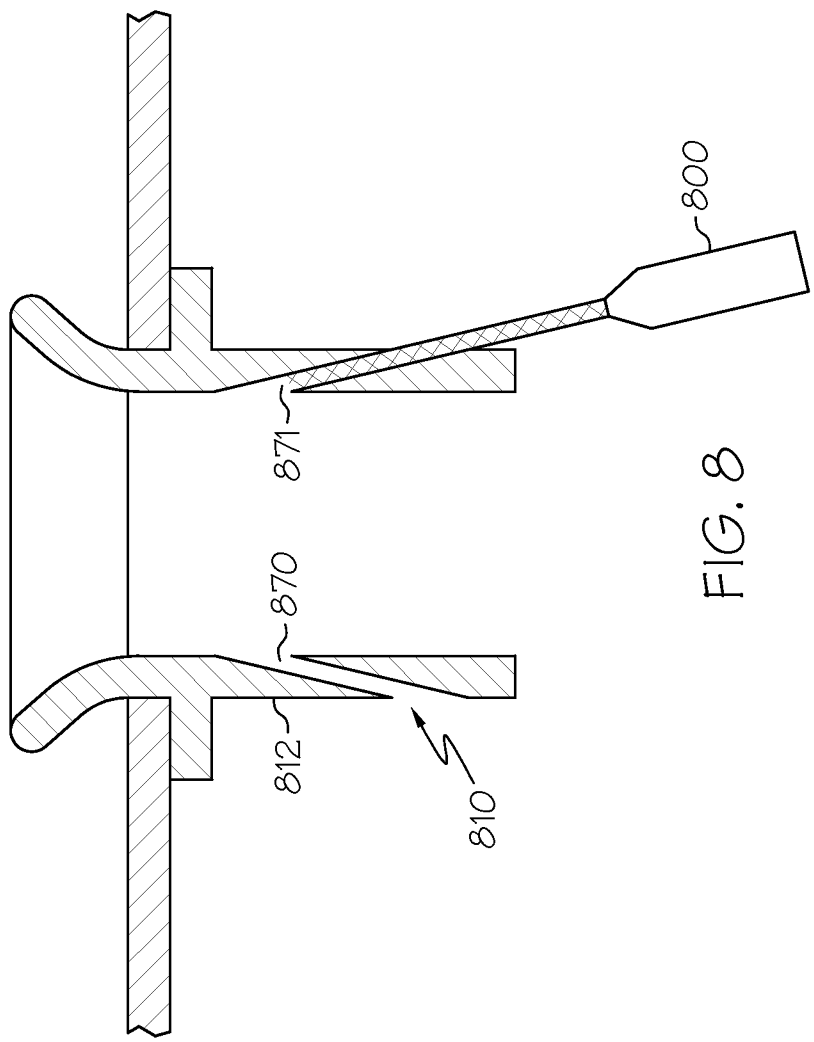


FIG. 8

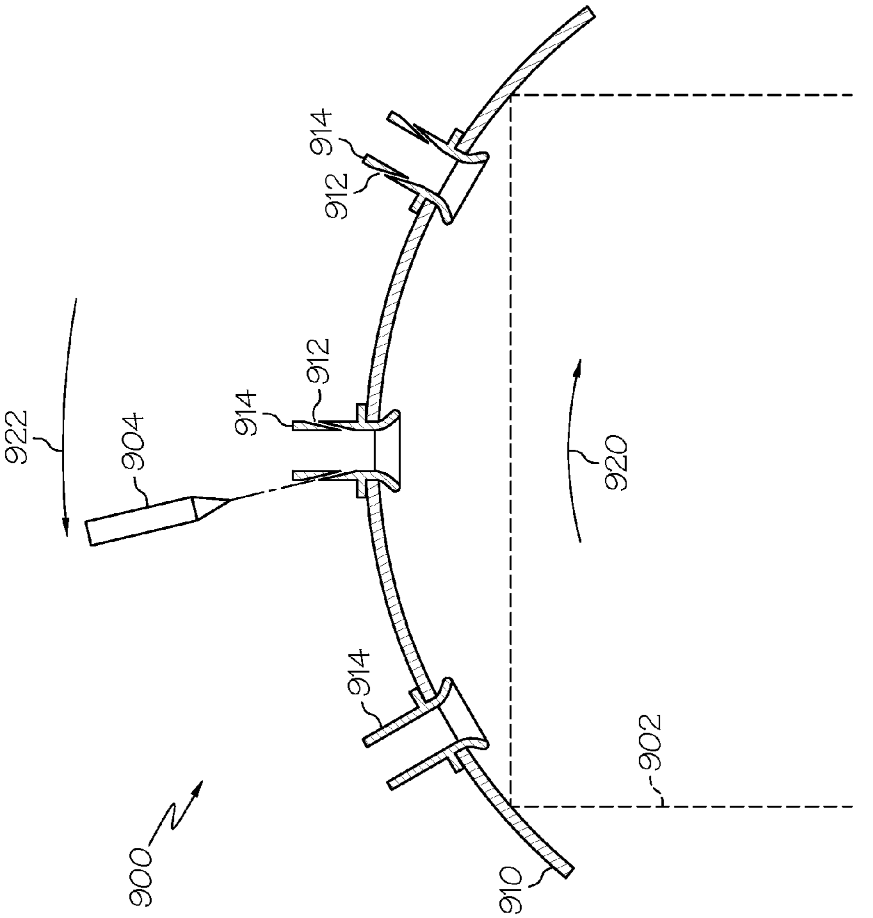


FIG. 9

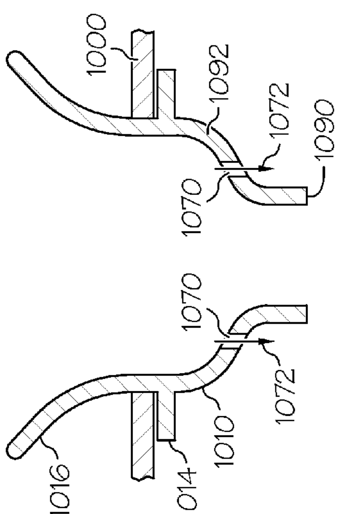


FIG. 10

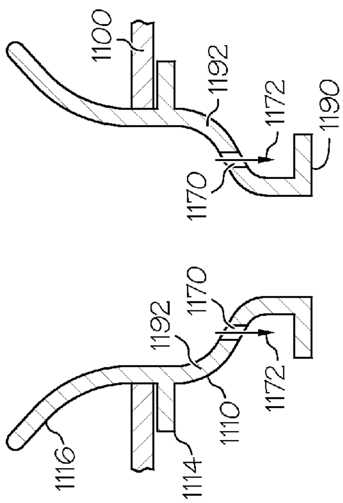


FIG. 11

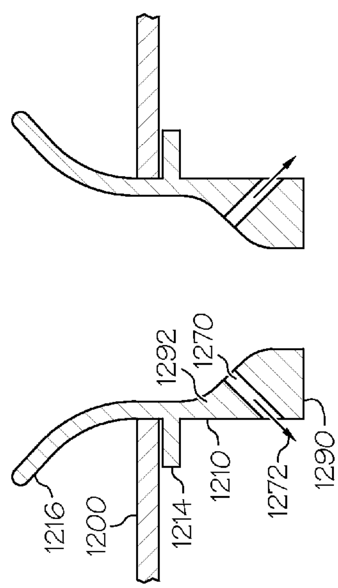


FIG. 12

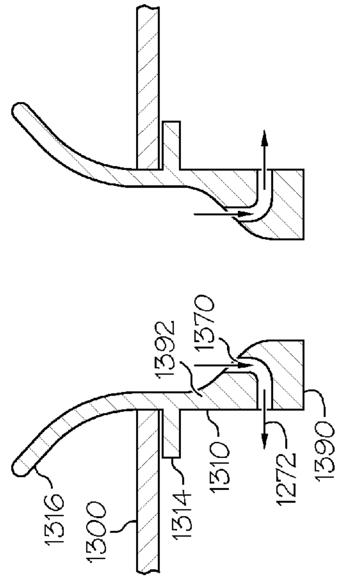


FIG. 13

COMBUSTORS WITH QUENCH INSERTS

TECHNICAL FIELD

The following discussion generally relates to gas turbine engine combustors, and more particularly, to combustors with quench inserts and methods for installing the same.

BACKGROUND

Gas turbine engines, such as those used to power modern commercial aircraft, typically include a compressor for pressurizing a supply of air, a combustor for burning fuel in the presence of the pressurized air, and a turbine for extracting energy from the resultant combustion gases. The combustor typically includes radially spaced apart inner and outer liners. The inner and outer liners generally define an annular combustion chamber between the compressor and the turbine. A number of circumferentially distributed fuel injectors typically project into the forward end of the combustion chamber to supply the fuel to the combustion chamber, and one or more rows of circumferentially distributed air admission holes in the liners admit air into the combustion chamber for combustion.

Modern combustors generally attempt to operate at very high temperatures, to achieve high operability, and to produce relatively low gaseous pollutant emissions during combustion, particularly oxides of nitrogen (NOx). One type of combustor that may provide one or more of these advantages is a rich burn, quick quench, lean burn (RQL) combustor, which includes the following three serially-arranged combustion zones: a rich burn zone at the forward end of the combustor, a quench or dilution zone downstream of the rich burn zone, and a lean burn zone downstream of the quench zone. By precisely controlling the stoichiometries between the air and fuel in each zone, high-temperature excursions can be reduced and the resulting NOx emissions can be minimized. The design and development of the quench zone geometry is commonly one of the primary challenges in the successful implementation of low-emissions RQL combustors. However, at times, designs that provide desired quench zone characteristics may adversely impact cooling schemes for the combustor components.

Accordingly, it is desirable to provide RQL combustors with a geometry that promotes low NOx emissions and increased operability while maintaining adequate cooling for the combustor components. Furthermore, other desirable features and characteristics of the present invention will become apparent from the subsequent detailed description of the invention and the appended claims, taken in conjunction with the accompanying drawings and this background of the invention.

BRIEF SUMMARY

In accordance with an exemplary embodiment, a combustor is provided for a turbine engine. The combustor includes a first liner having a first hot side and a first cold side; a second liner having a second hot side and a second cold side, the second hot side and the first hot side forming a combustion chamber therebetween. The combustion chamber is configured to receive an air-fuel mixture for combustion therein. The combustor further includes an insert having a body portion extending through the first liner and terminating at a tip, the body portion configured to direct air flow into the combustion chamber. The insert further includes a cooling hole defined in the body portion and configured to direct a first portion of the air flow toward the tip as cooling air.

In accordance with another exemplary embodiment, a method is provided for installing an insert in an air admission hole of a combustor liner. The insert includes an inlet portion, a body portion extending from the inlet portion with a tip on an end opposite the inlet portion, and a shoulder circumscribing the body portion. The combustor liner has a hot side and a cold side. The method includes inserting the inlet portion through the air admission hole from the hot side to the cold side until the shoulder abuts the hot side; deforming the inlet portion such that the inlet portion has an outer diameter greater than a diameter of the air admission hole; and drilling a cooling hole through the body portion from an interior surface to an exterior surface.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will hereinafter be described in conjunction with the following drawing figures, wherein like numerals denote like elements, and

FIG. **1** is a cross-sectional view of a gas turbine engine according to an exemplary embodiment;

FIG. **2** is a partial, cross-sectional side elevation view of the combustor section of FIG. **1** in accordance with an exemplary embodiment;

FIG. **3** is an enlarged portion of an insert in the combustor of FIG. **2** in accordance with an exemplary embodiment;

FIG. **4** is a flow chart of a method for installing inserts in a combustor liner in accordance with an exemplary embodiment;

FIG. **5** is an enlarged portion of a combustor illustrating an installation step of the method of FIG. **4** in accordance with an exemplary embodiment;

FIG. **6** is an enlarged portion of a combustor illustrating another installation step of the method of FIG. **4** in accordance with an exemplary embodiment;

FIG. **7** is an enlarged portion of a combustor illustrating another installation step of the method of FIG. **4** in accordance with an exemplary embodiment;

FIG. **8** is an enlarged portion of a combustor illustrating another installation step of the method of FIG. **4** in accordance with an exemplary embodiment;

FIG. **9** is a schematic view of a drilling set-up in the method of FIG. **4** in accordance with an exemplary embodiment; and

FIGS. **10-13** are cross-sectional views of inserts in accordance with additional exemplary embodiments.

DETAILED DESCRIPTION

The following detailed description is merely exemplary in nature and is not intended to limit the invention or the application and uses of the invention. Furthermore, there is no intention to be bound by any theory presented in the preceding background or the following detailed description.

Exemplary embodiments described herein provide a combustor having single- or double-walled liners with an insert to guide pressurized air through the liner and into the combustion chamber. During installation, each insert generally includes a tubular body portion that is inserted from the hot side through the liner until a shoulder circumscribing the body portion abuts the hot side. A tool then deforms an inlet portion projecting through the cold side to form a flared inlet portion. The flared inlet portion and shoulder capture the liner to retain the insert relative to the liner without welding or other bonding techniques. Cooling holes are then laser drilled into the body of the insert to provide cooling air flow to the tip of the insert during operation.

FIG. **1** is a simplified, cross-sectional view of a gas turbine engine **100** according to an exemplary embodiment. The engine **100** may be disposed in an engine case **110** and may include a fan section **120**, a compressor section **130**, a combustion section **140**, a turbine section **150**, and an exhaust section **160**. The fan section **120** may include a fan **122**, which draws in and accelerates air. A fraction of the accelerated air exhausted from the fan **122** is directed through a bypass section **170** to provide a forward thrust. The remaining fraction of air exhausted from the fan **122** is directed into the compressor section **130**.

The compressor section **130** may include a series of compressors **132** that raise the pressure of the air directed from the fan **122**. The compressors **132** then direct the compressed air into the combustion section **140**. In the combustion section **140**, the high pressure air is mixed with fuel and combusted. The combusted air is then directed into the turbine section **150**.

The turbine section **150** may include a series of turbines **152**, which may be disposed in axial flow series. The combusted air from the combustion section **140** expands through and rotates the turbines **152** prior to being exhausted through a propulsion nozzle **162** disposed in the exhaust section **160**. In one embodiment, the turbines **152** rotate to drive equipment in the engine **100** via concentrically disposed shafts or spools. Specifically, the turbines **152** may drive the compressor **132** via one or more rotors **154**.

FIG. **2** is a more detailed cross-sectional view of the combustion section **140** of FIG. **1**. In FIG. **2**, only half the cross-sectional view is shown; the other half would be substantially rotationally symmetric about a centerline and axis of rotation **200**. The combustion section **140** of FIG. **2** is an annular combustion section **140**, although aspects of exemplary embodiments described herein may also be useful in can combustors, can-annular combustors, and other types of combustors. Moreover, exemplary embodiments may find beneficial uses in many industries, including aerospace and particularly in high performance aircraft, as well as automotive and electrical generation.

The combustion section **140** includes a radially inner case **202** and a radially outer case **204** concentrically arranged with respect to the inner case **202**. The inner and outer cases **202** and **204** circumscribe the axially extending engine centerline **200** to define an annular pressure vessel **206**. The combustion section **140** also includes a combustor **208** residing within the annular pressure vessel **206**. The combustor **208** is defined by an outer liner **210** and an inner liner **212** that is circumscribed by the outer liner **210** to define an annular combustion chamber **214**. The liners **210** and **212** cooperate with cases **204** and **202** to define respective outer and inner air plenums **216** and **218**.

The combustor **208** includes a front end assembly **220** comprising a dome assembly **222**, fuel injectors **224**, and fuel injector guides **226**. One fuel injector **224** and one fuel injector guide **226** are shown in the partial cross-sectional view of FIG. **2**. In one embodiment, the combustor **208** includes a total of sixteen circumferentially distributed fuel injectors **224**, but it will be appreciated that the combustor **208** could be implemented with more or less than this number of fuel injectors **224**. Each fuel injector **224** introduces a swirling, intimately blended fuel-air mixture that supports combustion in the combustion chamber **214**.

The depicted combustor **208** is a rich burn, quick quench, lean burn (RQL) combustor. During operation, a portion of the pressurized air enters a rich burn zone RB of the combustion chamber **214** by way of passages in the front end assembly **220**. This air is referred to as primary combustion air because it intermixes with a stoichiometrically excessive quantity of fuel introduced through the fuel injectors **224** to support initial combustion in the rich burn zone RB. The rich stoichiometry of the fuel-air mixture in the rich burn zone RB produces a relatively cool, oxygen-deprived flame, thus preventing excessive NOx formation and guarding against blowout of the combustion flame during any abrupt reduction in engine power.

The combustion products from the rich burn zone RB, which include unburned fuel, then enter a quench zone Q. Jets **252** and **262** flow from the plenum **216** into the quench zone Q through air admission holes **250** and **260**, respectively, in the outer liner **210**. Similarly, jets **272** and **282** flow from the plenum **218** into the quench zone Q through air admission holes **270** and **280**, respectively, in the inner liner **212**. Additional holes with similar features and arrangements may be provided in both the outer and inner liners **210** and **212** to provide additional quench jets to the combustion chamber **214**. The air admission holes **250**, **260**, **270**, and **280** in the outer and inner liners **210** and **212** are discussed in further detail below.

The jets **252**, **262**, **272**, and **282** are referred to as quench air because they rapidly mix the combustion products from their stoichiometrically rich state at the forward edge of the quench zone Q to a stoichiometrically lean state at, or just downstream of, the aft edge of the quench zone Q. The quench air rapidly mixes with the combustion products entering the quench zone Q to support further combustion and release additional energy from the fuel. Since thermal NOx formation is a strong time-at-temperature phenomenon, it is important that the fuel-rich mixture passing through the quench zone be mixed rapidly and thoroughly to a fuel-lean state in order to avoid excessive NOx generation. Thus the design of the quench air jet arrangement in an RQL combustor is important to the successful reduction of NOx levels.

Finally, the combustion products from the quench zone Q enter a lean burn zone LB where the combustion process concludes. As the combustion products flow into the lean burn zone LB, the air jets **252**, **262**, **272**, and **282** are swept downstream and also continue to penetrate radially and spread out laterally and intermix thoroughly with the combustion gases.

FIG. **3** is a cross-sectional view of an exemplary air admission hole **250** suitable for use in a combustor, e.g., the combustor **208** of FIG. **2**. The position of air admission hole **250** generally corresponds to portion **300** of FIG. **2**. As such, FIG. **3** depicts the air admission hole **250** extending through the outer liner **210** between the plenum **216** and the combustion chamber **214**. However, the structure and function of the air admission hole **250** described below could also represent any of the air admission holes of the combustor **208**, including air admission holes **260**, **270**, and **280** (FIG. **2**).

In the exemplary embodiment depicted in FIG. **3**, an insert **310** is arranged in the air admission hole **250** to guide the jets **252** from the plenum **216**, through the air admission hole **250**, and into the combustion chamber **214**. Particularly, the plunged characteristics of the insert **310** assist the jets **252** in penetrating to the desired depth within the combustion chamber **214** for advantageous quench characteristics. Moreover, in one exemplary embodiment, the outer and inner liners **210** and **212** (FIGS. **2** and **3**) have effusion holes (not shown) that provide a cooling layer of air on the combustor side of the combustion chamber **214**. In some exemplary embodiments, the insert **310** decreases or eliminates any interference between the jet **252** and the effusion cooling layer.

As shown, the outer liner **210** is a single-walled liner with a cold side **350** that faces the plenum **216** and a hot side **352** that faces the combustion chamber **214**. In the embodiment shown in FIG. **3**, the insert **310** is formed from a single, discrete piece relative to the outer liner **210**. The insert **310** includes a body portion **312** that extends through the outer liner **210** and into the combustion chamber **214**. The body portion **312** is generally tubular and assists in guiding the jet **252** into the combustion chamber **214**. The body portion **312** may have an interior surface **380** that defines an interior passage for the jet **252** and an exterior surface **382** that faces the outer liner **210** and the combustion chamber **214**. The body portion **312** terminates at a tip **390**.

A shoulder **314** circumscribes the body portion **312** and abuts the hot side **352** of the outer liner **210**. The shoulder **314** generally extends in an axial direction to prevent the insert **310** from sliding out of the outer liner **210** in a radial direction towards the plenum **216**. In one exemplary embodiment, the shoulder **314** may be contoured in the axial-circumferential plane to locally match any contour of the hot side **352**. An inlet portion **316** extends in a radial direction from the body portion **312** and is flared or bell-shaped to guide the jet **252** into the insert **310**. The flared geometry of the inlet portion **316** serves to secure the insert **310** in the radial direction towards the combustion chamber **214** by abutting the cold side **350** of the outer liner **210**. In effect, the inlet portion **316** and shoulder **314** function to capture the outer liner **210** to retain the insert **310**, particularly in the radial direction, i.e., the inlet portion **316** and shoulder **314** prevent the insert **310** from sliding out of the air admission hole **250** into the outer plenum **216** or into the combustion chamber **214**.

Given this configuration, the insert **310** generally does not require additional securement to the outer liner **210** in the form of bonding, welding and/or additional components. As such, the insert **310** may be strain isolated with respect to both the cold side **350** and the hot side **352** in each of the radial, axial and circumferential directions to accommodate thermal growth differences.

As particularly shown in FIG. **3**, the insert **310** may include one or more cooling holes **370** for delivering a portion **372** of the jet **252** to the tip **390** of the insert **310** as cooling air. As depicted in FIG. **3**, the cooling holes **370** may extend from the interior surface **380** to the exterior surface **382** in the integral insert **310**. As such, the portion **372** of the jet **252** flow from the interior surface **380** of the insert body portion **312** to the exterior surface **382** of the insert body portion **312** to deliver cooling air to the tip **390**, particularly the exterior surface **382** of the tip **390**. In general, the cooling holes **370** may be defined by an inlet on the interior surface **380** of the body portion **312** and an outlet on the exterior surface **382**, particularly at or adjacent to the tip **390**.

The cooling holes **370** may be any suitable angle **374** in the radial-axial plane, as shown in FIG. **3**, and any suitable angle (not shown) in a circumferential direction, although more shallow angles **374** and thus, longer cooling holes **370**, may provide increased heat transfer from the body portion **312** of the insert **310** as the cooling air **372** flows therethrough. In one exemplary embodiment, the angle **374** of the cooling holes **370** may be, for example, about 20°. The radius or cross-sectional area of the cooling holes **370** may be any suitable dimensions with considerations for cooling requirements, combustion considerations, flow rates, and velocities.

As described above, the cooling holes **370** function to remove heat from the insert **310** via convective heat transfer. Additionally, the cooling air **374** flowing from the cooling holes **370** may at least partially buffer the tip **390** from the hot combustion gases of the combustion chamber **308** without unduly interfering with effusion cooling of the liner **210**, the combustion process, or the quench jets **252**. As described below, the cooling holes **370** may be selectively provided as needed for cooling the body portion **312**, particularly the tip **390**.

The dimensions of the insert **310** may vary as necessary or desired. For example, the body portion **312** may extend into the combustion chamber **214** to any suitable depth **340** with considerations for desired jet penetration and effusion cooling impact. The body portion **312** generally has an outer diameter **344** that approximates the diameter of the air admission hole **250** in the liner **210** for a secure fit and leakage minimization. The inner diameter **346** of the body portion **312** may depend on aerodynamic and other operational and installation characteristics. For example, the inner diameter **346** may depend on the desired quantity of air passing through the air admission hole **250** and the amount of cooling air **372** needed at the tip **390**. The shoulder **314** may extend to a length **342** that is greater than the diameter **344** of the air admission hole **250** without unduly interfering with operational and/or cooling performance. The inlet portion **316** may have a height **360**, diameter **362**, and curvature **364** for optimally guiding the jet **252** into the insert **310**. Generally, the curvature **364** is elliptical, i.e., with a changing radius of curvature. In other embodiments, the curvature **364** may have a constant radius of curvature or have straight sections. In general, based on the configuration of the insert **310**, the temperature profile of the combustion gases can be adjusted without compromising fuel-air mixing, which could lead to elevated levels of NOx. Additionally, based on the particular configuration of the cooling holes **370**, the temperature profile of individual inserts **310** may be adjusted, as described in greater detail below.

Some exemplary dimensions or design considerations will now be provided. As one example, the amount of air flow forming the jet **252** may be based on the overall aerodynamic design of the combustor. The outer diameter **344** of the body portion **312** may be, for example, about 0.06-0.1 inches larger than the inner diameter **346** and the inner diameter **346** may be, for example, 0.1-0.4 inches, although any suitable sizes may be provided. As noted above, the depth **340** may extend from the hot side **352** beyond the effusion cooling layer, such as, for example, about 0.075-0.15 inches. The length **342** of shoulder **314** may extend to any extent that prevents the insert from sliding through the air admission hole **250**, such as for example, about 0.02-0.03 inches. The inlet height **360**, inlet diameter **362**, and curvature **364** may generally be related to one another by CFD modeling. For example, each relative diameter **362** through the inlet **316** may be associated with a height **360** based on a polynomial equation that results in the curved inlet shape. As noted above, such an equation may be modeled based on various combinations of heights and diameters. One such suitable equation may generally be considered an elliptical shape. In such an embodiment, the radius of curvature (e.g., curvature **364**) may increase at from the outer extent of the inlet **316** to the body portion **312**. In one exemplary embodiment, the inlet portion **316** is designed such that the jet **252** makes a smooth transition into the insert **310**, without unnecessary turbulence, pressure loss, or flow separations.

Although the air admission hole **250** and corresponding insert **310** are generally circular in the depicted exemplary embodiments, the inlets and/or outlets of the air admission holes **250** and inserts **310** may be modified as necessary or desired. For example, the inlets of the air admission holes air admission holes **250** and inserts **310** may be a non-circular shape, including rectangular, racetrack, oval, and square.

Additionally, the air admission holes **250** and inserts **310** may be clocked if additional alignment or interleaving of the jets is desired to produce, for example, an upstream swirl and effusion film.

FIG. **4** is a flow chart of a method **400** for installing an insert in a combustor liner, such as insert **310** in outer liner **210**, in accordance with an exemplary embodiment, although the method **400** is applicable to inserts in any air admission hole of the inner or outer liner. FIGS. **5-9** depict installation steps of the method **400** and will be referenced in the description of FIG. **4** below.

In a first step **405** of the method **400**, an insert **310** is provided. At this stage, the insert **310** is generally configured as depicted in FIG. **5** and includes the tubular body portion **312** and the shoulder **314** circumscribing the body portion **312**. As also shown in FIG. **5**, the inlet portion **316** in this step generally has a circumference equal to that of the body portion **312**. In other words, the body portion **312** and the inlet portion **316** form a single tube shape with a generally constant diameter.

In a second step **410**, the inlet portion **316** is inserted through the air admission hole **250** of the outer liner **210** from the hot side **352** (i.e., in the direction **502**) until the shoulder **314** abuts the hot side **352**. Since the inlet portion **316**, at this stage, generally has the same circumference as the body portion **312** and the air admission hole **250**, the inlet portion **316** may pass through the air admission hole **250** from the hot side **352** without obstruction until the shoulder **314** abuts the hot side **352**.

In a step **415**, a working tool **510** is lowered in direction **504** to flare the inlet portion **316**, as is particularly shown in FIG. **6**. The working tool **510** may be lowered, for example, in a machine press (not shown). The working tool **510** has a contour **512** that matches the final geometry of the inlet portion **316**, including the height **360**, diameter **362**, and curvature **364** of the inlet portion **316**. As such, the geometric configuration of the inlet portion **316** may be precisely controlled by the geometry of the working tool **510**. Given the contour **512** and controlled precision of the working tool **510**, the deformation or flaring of the inlet portion **316** does not require a backing structure at the inlet portion **316** as a counter-force to the deformation. This results in an easier and simpler installation. A counter-press may be provided at the shoulder **314** to maintain the position of the insert **310** relative to the liner **210** as the working tool **510** deforms the inlet portion **316**. The working tool **510** is then removed from the insert **310**. As also noted above, the flared inlet portion **316** and shoulder **314** function to retain the insert **310** within the air admission hole **250** of the liner **210** without welding to the outer liner and without damage to any coatings on the outer liner **210** or the outer liner **210** itself. This installation method **400** further provides a versatile insert design by accommodating different hole diameters, insert dimensions, and inlet portion profiles. The resulting configuration provides an insert **310** in a single-walled combustor **208** that enables enhanced durability and/or operation. Conventional double-walled combustors typically do not encounter the same insert mounting issues as single-walled combustors since any inserts in a double-walled arrangement may be mounted on a cold wall or trapped between the two walls without consideration for strain isolation. Since single-walled combustors have no cold wall, conventional single-walled combustors typically do not use inserts since welding may yield undesirable thermal behavior. In contrast, exemplary embodiments discussed herein provide the advantages of inserts in single-walled combustors without the corresponding mounting issues. However, aspects discussed herein may also be applied to double-walled combustors.

Although FIGS. **5** and **6** depict forming the flared inlet portion **316** with a single working tool **510**, in other embodiments, more than one working tool may be used. For example, a first working tool **510** may partially flare the inlet portion **316** and a second working tool may be used to provide the final shape of the inlet portion **316**.

In a step **420**, if additional inserts **310** are to be installed, the method **400** returns to step **405** to mount the other inserts **310**. Otherwise, the method **400** proceeds to step **425**.

In a step **425**, a temperature profile of the liner **210** and inserts **310** is determined. As an example, FIG. **7** is a perspective view of a number of inserts **710**, **711**, **712**, and **713** similar to the inserts describe above installed on a liner **720**. The view of FIG. **7** depicts the hot side of the liner and the results of a Computational Fluid Dynamics (CFD) analysis. Particularly, it is generally desirable for hot combustion gases, represented by streamlines **730**, to flow around the inserts **710-713**. However, at times, the streamlines **730** may form a vortex or otherwise depart from smoothly flowing past the inserts **710-713**. These instabilities may result in elevated temperature on the insert **710-713**, particularly at the tip, as hot air is recirculated. As an example, inserts **711** and **713** have recirculating streamlines **730**, which if unaddressed, may result in localized elevated temperatures in areas **741** and **743**. As described below, cooling holes may be drilled in the inserts **710-713** at these areas **741** and **743** to prevent or mitigate elevated temperatures. Any number of cooling holes may be provided. For example, in the depiction of FIG. **7**, one hole may be provided in each area **741** and **743** (e.g., two holes in insert **711** and four holes in insert **713**).

Returning briefly to FIG. **4**, in a step **430**, cooling holes are drilled according to the temperature profile of step **425**. FIG. **8** is a cross-sectional view of an insert **810** similar to the inserts discussed above with a laser **800** drilling cooling holes **870** and **871**. In the view of FIG. **8**, the laser **800** has drilled cooling hole **870** and is in the process of drilling cooling hole **871**. Generally, the liner **802** may be mounted onto a support (not shown in FIG. **8**) and the laser **800** or the liner **802** may be positioned and repositioned to drill the cooling holes **870** and **871** at the appropriate locations, angles, and widths (or diameters). The laser drilling may continue, as necessary, for each of the inserts of the liner. As an example, FIG. **9** is a schematic view of a drilling set-up **900** in which a liner **910** is mounted on a support **902** and a drill **904** is positioned relative to the liner **910** to drill cooling holes **912** in inserts **914**. As a cooling hole **912** is completed, the liner **910** or drill **904** may be repositioned, as indicated by arrows **920** and **922**, to drill subsequent cooling holes **912**. As such, cooling holes **912** may be selectively provided in the areas that may be subject to elevated temperatures, thereby maintaining insert temperatures while minimizing cooling air.

The inserts described above generally make reference to the embodiment of the insert **310** shown in FIG. **3**. However, alternate embodiments of the insert may be provided. For example, FIGS. **10-13** are cross-sectional views of insert in accordance with additional exemplary embodiments.

In the embodiment of FIG. **10**, the insert **1010** has a flared inlet portion **1016** and shoulder **1014** to retain the insert **1010** relative to the liner **1000**. In this embodiment, the tip **1090** has a reduced diameter downstream of a transition portion **1092**. As such, the cooling holes **1070** may be provided in the transition portion **1092**, generally in a radial direction to provide cooling air **1072** to the tip **1090**. Since the orientations of the cooling holes **1070** are parallel to the quench jet, pressure losses may be minimized as air flows through the cooling holes **1070**.

In the embodiment of FIG. **11**, the insert **1110** has a flared inlet portion **1116** and shoulder **1114** to retain the insert **1110** relative to the liner **1100**. As in the embodiment of FIG. **10**, the tip **1190** has a reduced diameter downstream of a transition portion **1192**. However, unlike the embodiment of FIG. **10**, the tip **1190** further includes an axial flange **1194**. The cooling holes **1170** may be provided in the transition portion **1192**, generally in a radial direction to provide cooling air **1172** to the tip **1190**.

In the embodiment of FIG. **12**, the insert **1210** has a flared inlet portion **1216** and shoulder **1214** to retain the insert **1210** relative to the liner **1200**. In this embodiment, the insert **1210** has a reduced diameter downstream of a transition portion **1292**. Unlike the embodiment of FIG. **10**, the insert **1210** has a reduced diameter as a result of a thicker tip **1290**. In this embodiment, the cooling holes **1270** may be provided at an angle to deliver cooling air **1272** to the tip **1290**.

In the embodiment of FIG. **13**, the insert **1310** has a flared inlet portion **1316** and shoulder **1314** to retain the insert **1310** relative to the liner **1300**. Similar to the embodiment of FIG. **12**, the insert **1310** has a reduced diameter downstream of a transition portion **1392** resulting from a thicker tip **1390**. In this embodiment, the cooling holes **1370** may have compound directions, e.g., in a radial direction from an interior surface to an axial direction to the exterior surface. In each of the embodiments of FIGS. **11-13**, as well as the other embodiments, the cooling air flowing through the cooling holes (e.g., holes **1170**, **1270**, and **1370**) may be angled to initiate an effusion cooling on the inner liner (e.g., liner **1100**, **1200**, and **1300**). In other embodiments, effusion cooling may be omitted.

Accordingly, exemplary embodiments discussed herein provide a combustor with enhanced performance and emission characteristics while maintaining acceptable component temperatures. In particular, cooling holes are provided in the insert to provide cooling air to the tip of the insert in a simple, cost effective manner. Reduced tip temperatures may improve overall combustor durability. Additionally, the cooling holes may be selectively drilled based on a temperature profile of the combustors, thereby minimizing the cooling flow required.

While at least one exemplary embodiment has been presented in the foregoing detailed description of the invention, it should be appreciated that a vast number of variations exist. It should also be appreciated that the exemplary embodiment or exemplary embodiments are only examples, and are not intended to limit the scope, applicability, or configuration of the invention in any way. Rather, the foregoing detailed description will provide those skilled in the art with a convenient road map for implementing an exemplary embodiment of the invention. It being understood that various changes may be made in the function and arrangement of elements described in an exemplary embodiment without departing from the scope of the invention as set forth in the appended claims.

What is claimed is:

1. A combustor for a turbine engine, comprising:

a first liner having a first hot side and a first cold side;

a second liner having a second hot side and a second cold side, the second hot side and the first hot side forming a combustion chamber therebetween, the combustion chamber configured to receive an air-fuel mixture for combustion therein; and

an insert comprising a body portion extending through the first liner and terminating at a tip, the body portion configured to direct air flow into the combustion chamber,

the insert further including a cooling hole defined in the body portion and configured to direct a first portion of the air flow toward the tip as cooling air,

wherein the body portion has an interior surface and an exterior surface, the cooling hole extending from the interior surface to the exterior surface,

wherein the body portion is generally tubular,

wherein the first liner is a single-walled liner, and

wherein the tubular body portion has a longitudinal axis, and wherein the cooling hole extends from the interior surface to the exterior surface at an angle of less than 90° and greater than 0° relative to the longitudinal axis, wherein the cooling hole extends from an inlet on the interior surface to an outlet on the exterior surface, the angle being defined at the outlet relative to the external surface.

2. The combustor of claim **1**, wherein the cooling hole is at least partially defined in the exterior surface of the body portion proximate to the tip.

3. The combustor of claim **1**, wherein the body portion further comprises a shoulder circumscribing the body portion and abutting the first hot side, and an inlet portion coupled to the body portion and arranged relative to the first cold side such that the inlet portion and the shoulder capture the first liner therebetween to retain the insert.

4. The combustor of claim **1**, wherein the combustion chamber defines a rich burn zone, a quench zone, and a lean burn zone, and the insert is configured to introduce air into the quench zone.

5. The combustor of claim **1**, wherein the body portion projects into the combustion chamber.

6. The combustor of claim **1**, wherein the body portion includes an inlet portion opposite the tip, the inlet portion being flared to guide air into the insert.

7. The combustor of claim **1**, wherein the angle is approximately 20° relative to the longitudinal axis.

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